PREDICTING DOUGLAS-FIR DEFOLIATION FROM THE PERCENTAGE OF BUDS INFESTED BY THE WESTERN SPRUCE BUDWORM

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Abstract

Based on samples from 12 locations collected in British Columbia between 1977 and 1982, a regression model was developed for the relationship between percentage of buds of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, infested by western spruce budworm (WSB), *Choristoneura occidentalis* (Freeman), and the resulting stand defoliation. This relationship can be used to assess the budworm population in the early spring, either as a pre-treatment check or to predict damage.

Résumé

À partir d'échantillons prélevés dans 12 localités de la Colombie-Britannique entre 1977 et 1982, un modèle de régression a été construit pour corréler le pourcentage de bourgeons du douglas taxifolié (*Pseudotsuga menziesii* (Mirb.) Franco) infestés par la tordeuse occidentale de l'épinette (*Choristoneura occidentalis* [Freeman]), ainsi que la défoliation résultante des peuplements. Cette corrélation peut servir à évaluer les effectifs de la tordeuse au début du printemps, soit pour la vérification de prétraitement, soit pour la prévision des dégâts.

INTRODUCTION

The western spruce budworm (WSB), *Choristoneura occidentalis* (Freeman) (Lepidoptera:Tortricidae), is a chronic pest of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in British Columbia (Harris *et al.* 1985). The defoliation resulting from larval feeding can cause a serious loss of wood volume through growth reduction and mortality (Alfaro *et al.* 1982). There is a relationship between severity of defoliation and damage to the tree (Alfaro 1986).

The life cycle of the WSB in British Columbia is, briefly, as follows. Eggs, laid in early August, hatch within 12 days and the larvae seek shelter under lichen or bark scales. There they spin hibernaculae in which the overwinter as second instar larvae. In May they begin to mine needles or expanding flower and foliage buds. On completion of six instars they pupate in late June to mid-July; adults emerge 12-18 days later (Unger 1986).

In order to treat infestations of this insect with pesticides, infested areas must be ranked in terms of priority for treatment. Factors that are considered in assigning a priority ranking to a stand are the stand value and the expected losses: the latter being related to the severity of defoliation. Treatments are usually aimed at controlling the most destructive stages, larval instars 5 and 6.

Methods of predicting expected defoliation based on pheromone trap catches, samples of eggs masses, overwintering larvae or early spring larvae, have been investigated (Carolin and Coulter 1972; Twardus 1985) and some of these, especially egg mass counts, are used routinely as predictive indices (Shore 1985). However, pheromone trap catches have not yet been calibrated for predicting subsequent defoliation in British Columbia and, as with egg mass sampling, are so far removed in time from the damaging feeding state that various mortality factors may reduce budworm populations and seriously affect predictions. Sampling overwintering larvae is laborious because a chemical wash is required to extract the tiny larvae from their hibernaculae, and since this method has not been fully developed and calibrated for WSB it is seldom used (Twardus 1985).

Sampling larval instars 3 and 4, in the early spring, as they infest the opening buds, provides a pre-treatment estimate of the population density after fall and winter mortality. Larvae of WSB infest buds just prior to, or as, they are opening. This is a time of relative population stability for about 10 days (Carolin and Coulter 1972; Twardus 1985), when temperatures are cool at nights, development is slow and larval mortality is low. These make ideal conditions for sampling if carefully timed (Morris 1955; Carolin and Coulter 1972).

It is the purpose of this paper to present information on the relationship between the percentage of Douglas-fir buds infested by WSB and subsequent defoliation, and to show how the relationship can be used to improve the management of this serious forest pest.

METHODS AND MATERIALS

Douglas-fir trees were sampled repeatedly at 12 locations between 1977 and 1982. A total of 60 estimates of percentage of WSB-infested buds and resultant defoliation were obtained (all locations were not sampled every year). The estimates were made by removing mid-crown branch tips, using pole pruners, until 100 buds were examined on each of three dominant or codominant trees. The percentage of infested buds for the location was then calculated as the average of the three individual tree estimates. In late summer of the same year, after WSB larval feeding ended, defoliation was assessed for the location by examining 10 dominant or codominant trees selected at random. The percentage defoliation of current year's foliage was estimated separately for the upper-, mid-, and lower-crown levels using binoculars. The defoliation per tree was calculated as the average of the three crown level estimates, and the defoliation per stand as the average of the 10 single tree estimates.

The relationship between the percentage of infested buds and subsequent defoliation was examined using a number of linear and non-linear regression models. Prior to the regression analysis the data were tested for autocorrelation using the Durbin-Watson statistic which indicated no significant autocorrelation ($P>0.05$). The models that best fitted the data were selected based on comparisons of R^2 and F values, and on examination of plot residuals.

RESULTS AND DISCUSSION

Preliminary analysis indicated a statistically significant relationship between percent defoliation and the percentage of infested buds. However, it was observed that in the final year or two of an infestation there could be a high percentage of infested buds, but little or no defoliation. This was the result of high WSB mortality in the period following bud sampling. The relationship was re-examined omitting those cases where the population had collapsed following sampling, leaving 46 sample points.

After examination of many possible regression models the one that best fitted the data was:

$$\ln(\text{Defoliation} + 1) = A + B \ln(\text{Buds} + 1) \qquad [1]$$

where ln = natural logarithm
Defoliation = average tree defoliation (%) per location
Buds = % buds infested by WSB per location
$A = -0.3491$
$B = 1.2053$
$R^2 = 0.76$, $F = 136.8$, $MSE = 0.667$, $P < 0.01$, $N = 46$

However, the simple linear model (Fig. 1):

$$\text{Defoliation} = A + B(\text{Buds}) \qquad [2]$$

where $A = -0.189$
$B = 1.835$
Defoliation and buds are defined as above
$R^2 = 0.68$, $F = 94.4$, $MSE = 0.319$, $P < 0.01$, $N = 46$

also gave an acceptable fit.

Since we omitted the sample points from locations where the WSB population collapsed following sampling, our method will overestimate defoliation in such cases and therefore,

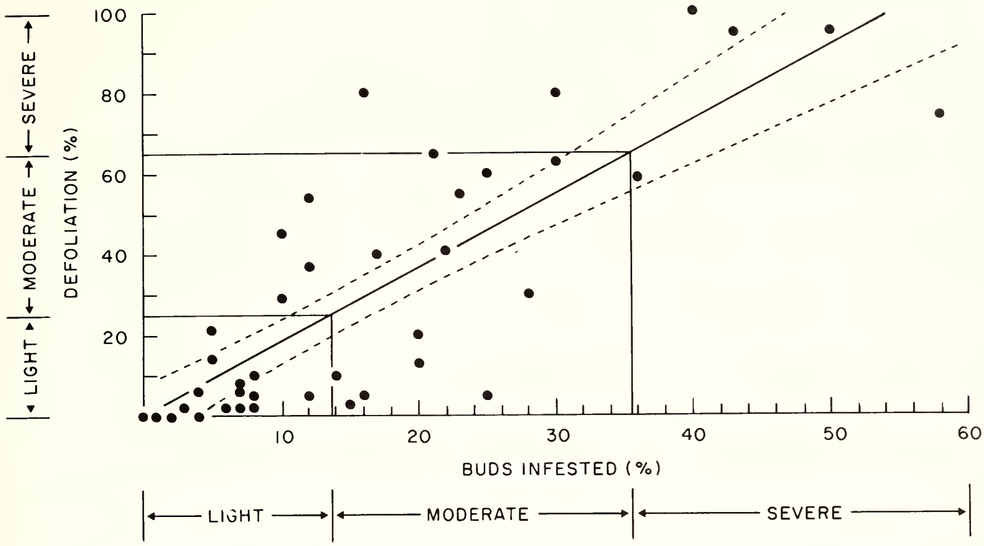

Figure 1. The relationship between the percentage of Douglas-fir buds infested by western spruce budworm and subsequent average tree defoliation; $y = -0.189 + 1.835x$, $R^2 = 0.68$ (---- = 95% confidence limits). Thresholds for light, moderate and severe defoliation are shown.

provides a worst case scenario. This does not decrease its usefulness for pre-treatment classification of potential stand defoliation.

Working in eastern Oregon, Carolin and Coulter (1972) developed a linear relationship to predict a current year's defoliation from the number of larvae per 1000 buds. For comparison, we transformed their data to percentage of infested buds by dividing the independent variable by 10. We assumed from their methods that they were sampling primarily larvae infested buds. Our linear model was remarkably similar to that found by Carolin and Coulter (1972) (Fig.2). For this reason and for simplicity of use and understanding we recommend the use of the linear model [2], even though the logarithmic model fitted the data slightly better.

These relationships can be used to develop broad defoliation severity classes corresponding to ranges of percentage of infested buds. Based on our models, we calculated the percentage of buds infested that result in the defoliation severity classes used in British Columbia by the Forest Insect and Disease Survey of the Canadian Forestry Service (Table 1).

We compared the defoliation severity predictions based on our models with data for 57 stands in British Columbia collected between 1984 and 1986, where average percentage of buds infested and subsequent estimates of stand defoliation severity from the air were available. Although our method was based on ground observations of defoliation, and the aerial estimates of defoliation use more subjective criteria (Shore 1985), a comparison is useful. Our linear model accurately predicted aerial defoliation severity class for 32 stands (56%), it overestimated in 22 stands (39%) and underestimated in 3 stands (5%). The corresponding predictions for the logarithmic model agreed in 65%, overestimated in 30%, and underestimated in 5% of the stands. This suggests that defoliation is rated lower by the

Table 1. Percentage of buds infested by western spruce budworm and expected defoliation of Douglas-fir

Buds infested (%)		Expected defoliation	
Linear	Logarithmic	Class	Percent
0	0	none	0
1-13	1-19	light	1-25
14-35	20-41	moderate	26-65
36-100	42-100	severe	66-100

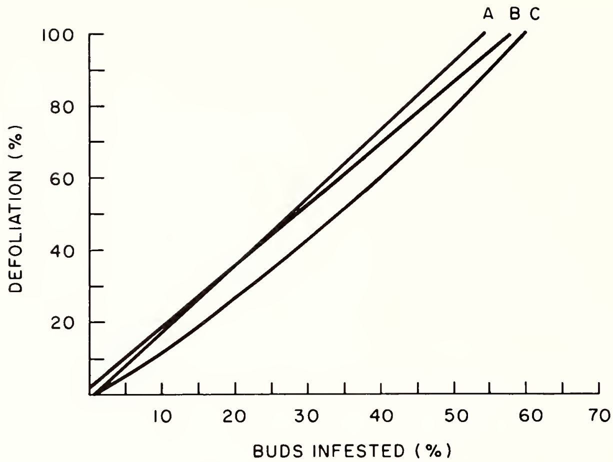

Figure 2. A comparison of three models to describe the relationship between the percentage of Douglas-fir buds infested by western spruce budworm and subsequent average tree defoliation. A = linear model in Fig. 1, B = Carolin and Coulter (1972), C = logarithmic model (see text).

aerial classification system than it is from the ground. The higher classification thresholds produced by the logarithmic model agree more closely with aerial defoliation estimates that do those of the linear model.

The timing of sampling for percentage of infested buds is critical. Shepherd (1983) described the relationship between temperature (in degree days), bud and WSB development for some interior locations in British Columbia. He found that larvae averaged instar 2.9 and were beginning to penetrate the buds at approximately 265 degree-days (over a 5° C threshold) and remain in their protective feeding sites, consuming the expanding foliage, until the buds reach stage 6 (372 degree-days). Sampling should be conducted when the buds are in stages 3 to 6, described by Shepherd (1983) (which includes photographs) as follows:

stage 3-white scale stage: bud all light brown or yellow, scales separated to reveal white layers underneath.

stage 4-columnar stage: bud columnar shape with a rounded tip, green needles visible beneath semi-transparent scales.

stage 5-split stage: bud split open to reveal green needles, bud cap may still be present, needles still tight together.

stage 6-brush stage: bud cap gone, needles flaring but little shoot growth so needles appear to arise from one location

Feeding in the buds occurs for a period of about 3-4 weeks (Shepherd 1983).

In the event of a budworm infestation, managers are faced with the task of preparing for a possible spray operation several months ahead of the damage. In order to provide enough time for this complex operation, preliminary spray plans should be based on egg mass surveys conducted in the fall (Shore 1985; Carolin and Coulter 1972; Twardus 1985). Sampling infested buds in the spring for predicting expected current foliage defoliation, should serve a useful purpose for refining the spray plans by, for example, avoiding the treatment of areas where the population has collapsed through winter mortality.

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SURVIVAL OF SELF-MARKED MOUNTAIN PINE BEETLES EMERGED FORM LOGS DUSTED WITH FLUORESCENT POWDER

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Abstract

Mountain pine beetles, *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae), were allowed to emerge in the laboratory from naturally infested lodgepole pine bolts, which had been heavily dusted with dry fluorescent (Day-Glo) powder. Emergent beetles were collected daily and stored at 5°C. Mortality was assessed daily for 21 days, after which the insects were killed. All dead beetles were examined under UV light for the presence and degree of marking. The survival of marked beetles was compared to that of unmarked beetles from control bolts. Analysis of variance showed no difference in mortality rate due to the treatment.

Résumé

On a épandu abondamment une poudre fluorescente sàche (Day-Glo) sur des billes de pin tordu infestés naturellement par des dendroctones du pin ponderosa (*Dendroctonus ponderosae* Hopk.) Coleoptera: Scolytidae). On a recueilli chaque jour les ensectes émergents et on les a placés dans une enceinte réfrigérée à 5°C. On a contrôlé la mortalité chaque jour pendant 21 jours, puis on a tué les insectes. On a examiné tous les insectes morts sous un éclairage UV pour connaître le degré de marquage. On a comparé la survie des insectes marqués à celle d'insectes non marqués ayant émergé des billes témoins. D'après l'analyse de la variance, le tratiement n'a eu aucun effet sur le taux de mortalité.

INTRODUCTION

An ongoing series of field experiments to study the dispersal behavior of mountain pine beetles (mpb), *Dendroctonus ponderosae* Hopk., was begun in 1982 near Riske Creek, in the Cariboo Forest Region of B.C. These experiments required the development of techniques suitable for field-marking large numbers of emergent mpb used in release-recapture experiments.

Fluorescent powders have been used extensively as markers on insects and are usually non-toxic, readily available and inexpensive (Gangwere *et al* 1964; Gara 1967; Moffitt and Albano 1972; Schmitz 1980). Powders have been applied to insects using vacuum chambers (Dunn and Michalas 1963; Moffitt and Albano 1972; Linton *et al* 1987), or the insects have